Fig. 2. Portion of the same, enlarged: showing the solid axis, the common canal, and the cellules.

Fig. 3. Transverse section of *Diplograpsus teretiusculus*, His.: showing the axis as a transverse plate or partition.

Fig. 4. *Diplograpsus teretiusculus*, His., nat. size: showing the proximal extension of the axis, or radicle (*a*), and the distal extension (*b*).

Fig. 5. Central portion of *Dichograpsus Logani*, Hall, sp., from a specimen collected by the author from the Skiddaw Slates: showing the branched funicle and the celluliferous stipes.

Fig. 6. Central disk and funicle of *Dichograpsus octobrachiatus*, Hall, sp. One of the divisions of the funicle (*a*) is shown prolonged into a celluliferous style (*b*).

Fig. 7. *Diplograpsus*, n. sp.: showing a disk at the proximal extremity. Collected by the author at Garple Linn, near Moffat.

Figs. 8, 9, 10. Varieties of *Diplograpsus bicornis*, Hall. Fig. 8. Normal form. Fig. 9. Variety with a rudimentary disk or cup; collected by Prof. Harkness at Glenkiln Burn, Dumfriesshire. Fig. 10. Variety with a fully developed disk, after Hall.

Fig. 11. *Diplograpsus vesiculosus*, n. sp.: showing the distal extremity of the axis expanded into a pointed vesicle. Collected by the author at Dobb's Linn, near Moffat.

Fig. 12. Germ of a monoprionidian Graptolite, enlarged.

Fig. 13. Germ of a diprionidian Graptolite, enlarged.

Fig. 14. *Didymograpsus flaccidus*, Hall, nat. size (recently described by Mr. W. Carruthers under the name of *D. elegans*). This form could obviously never have been attached, but must have been free.

Fig. 15. *Helicograpsus* (*Graptolithus*) *gracilis*, Hall, sp., nat. size: *a*, funicle: *b*, *b*, celluliferous stipes. From a specimen collected by the author at Glenkiln Burn, Dumfriesshire.

Fig. 16. Non-celluliferous stem, or funicle, of *Dendrograpsus Hallianus*, Prout, after Hall. This species may perhaps have been attached.

Fig. 17. Portion of the celluliferous branches of the same.

Fig. 18. *Diplograpsus* resembling *D. teretiusculus*, His., but furnished with two lateral spines in addition to the central radicle.

Fig. 19. *Corynoides calicularis*, Nich., enlarged. This form is allied to the Graptolites, but probably represents a different order.

Fig. 20. *Tetragrapsus quadribrachiatus*, Hall, sp.: showing the funicle, radicle, and celluliferous stipes.

X.—*On the Miocene Flora of the Polar Regions.* By Professor O. Heer *.

The numerous expeditions sent some years ago into the arctic regions have been, in every respect, productive in a scientific point of view. The bold navigators who explored the polar regions, surmounting the greatest difficulties, used every effort to bring back whatever they supposed might possess interest. Geology has had its share in the results of these researches. A considerable number of fossil plants

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derived from these explorations have been deposited in various museums, amongst others in those of Dublin, London, Copenhagen, and Stockholm. These precious materials have been placed at my disposal; and thus I have been enabled to examine a great quantity of fossil plants found in the north of Canada, near the Mackenzie River, on Banks Land, in North Greenland, in Iceland, and Spitzbergen. The study of these has led me to some important results with regard to the distribution of plants during the epochs preceding that in which we live. I have also been able to draw from them some interesting conclusions as to the climate which was then enjoyed by the countries situated around the North Pole.

The Arctic fossil Flora, in the present state of our knowledge, consists of 162 species. The Cryptogamia include 18 species, 9 of which are fine Ferns of large size, which probably covered the soil of the forests. Among the others we must note some little Fungi, which then formed spots and small points upon the leaves of trees, as the analogous species do at the present day. Among the Phanerogamia we find 31 species of Coniferæ, 14 species of Monocotyledons, and 99 species of Dicotyledons. Judging of these from the allied species in existing nature, 78 of them were trees, and 50 shrubs. Thus, therefore, 128 species of ligneous plants were then diffused over the polar regions. Among the Coniferæ we remark *Epiceæ*, Junipers, and Pines, most of which resemble American species. One of the most remarkable species is the *Pinus MacClurii*, very nearly related to *Pinus alba* of Canada. Of this, MacClure and his companions brought back cones obtained from Banks Land; and they observed the trunk in the remarkable mountains of fossil wood discovered in that country. The Miocene beds of Iceland have furnished seven species belonging to Pines or Junipers. The *Sequoiæ* (Wellingtonias) are still more abundant than the pines; this genus played a very important part in the Miocene period, and is found fossil in Europe, Asia, and America. At the present day it includes only two species (*Sequoia sempervirens* and *S. gigantea*), confined exclusively to California. These are the last representatives of this remarkable genus, to which belong the largest trees in the world. We find four species of it in the Miocene beds of the polar regions, three of which also occur at the same level in Central Europe. At this period *Sequoia Langsdorffii* was the most abundant tree in the north of Greenland; and we are acquainted not only with its branches and their leaves, but also with its flowers, cones, and seeds. It occurs also in the north of Canada, in Vancouver's Island, Germany, Switzerland, and Italy, and is very nearly allied to *S. sempervirens*, from which it is distinguished only by the size of its cones, which are larger and composed of more scales. *Sequoia Sternbergii*, which was abundant in Iceland, is very nearly related to *S. gigantea*; whilst *S. Couttsiæ*, which is found in Greenland, at Disco and Ataneverdlak, is intermediate between *S. Langsdorffii* and *S. Sternbergii*. The family of the Cypresses is richly represented by three genera—*Taxodium*, *Thujopsis*, and *Glyptostrobus*. The latter two are still in existence in Japan; the *Taxodia* occur in North America. *Glyptostrobus europæus* usually accompanies the *Sequoia Langsdorffii*, as also does *Taxodium dubium*, of which the branches, leaves, and cones were discovered at Ataneverdlak, and which has also been found ou Spitzbergen, at about 78° N. latitude. *Thujopsis europæa* is much rarer; its elegant branches have been found in North Greenland, and they are identical with those obtained from amber and at Armillan (near Narbonne).

Among the Taxineæ we remark a *Salisburia* from Greenland; this genus now occurs in the wild state only in Japan.

The number of *leafy trees* is so considerable that we can only indicate a few species. Several of them resemble trees of our countries; such are the *Beeches* and *Chestnuts*, which are still found in North Greenland at 70° N. latitude. A species of Beech (*Fagus Deucalionis*) is extremely near our common Beech (*Fagus sylvatica*); the leaves are of the same form and dimensions, and have the same nervures, but they are denticulated only at the extremity. This tree was, apparently, diffused through all the northern regions, since we meet with it in Greenland, Iceland, and Spitzbergen. The *Oaks* are still more varied; we count eight species in Greenland, most of them having large, elegantly denticulated leaves; they have some relation to American species. One of them (*Quercus Olafsoni*), which may be traced from the north of Canada to Greenland and Spitzbergen, is the analogue of *Quercus prinus* of the United States. A *Platanus* (*P. aceroides*) was also spread over all these countries; it is even met with in the Eisfjord in Spitzbergen. The *Poplars* furnish a still greater number of individuals than the genera just cited. Two species (*Populus Richardsoni* and *P. arctica*), with *Sequoia Langsdorffii*, were the commonest trees of the polar zone. We can trace them from the Mackenzie to Spitzbergen. The *Willows* are very rare, which may well surprise us when we consider that they now form one-fourth of the woody plants of the arctic zone. The *Birches* were abundant in Iceland, where we also remark a fine species of *Tulip-tree* and a *Maple* (*Acer otopteryx*). In Greenland we find a *Walnut*, a *Mag-*

nolia with coriaceous leaves (*M. Inglefieldi*), and a *Plum* (*Prunus Scottii*); and in Spitzbergen a large-leaved *Lime-tree* (*Tilia Malmgreni*). Side by side with these trees, which are analogous to those of the present epoch, we observe several exceptional forms, from the presence of which it is difficult to draw any conclusions. One of these species, which possesses large coriaceous leaves (*Daphnogene Kanii*), probably belongs to the family Laurineæ; four others (*Macclintockia* and *Hahea*) are probably Proteaceæ. It is difficult to judge what would have been the habit of these plants. With regard to others, however, analogy indicates that, in all probability, they were shrubs. Thus we find a *Nut-tree* (*Corylus MacQuarrii*) which was diffused through all the polar regions, and occurred in Spitzbergen at 78° N. latitude, as also a species of Alder (*Alnus Kefersteinii*). From Greenland we have species of *Rhamnus*, *Paliurus*, *Cornus*, *Ilex*, *Cratægus*, *Andromeda*, and *Myrica*, which ascend to 70° N. latitude. Sarmentose plants were not wanting; a species of *Ivy* (*Hedera MacClurii*) has been found on the shores of the Mackenzie, and of *Vines* two species in Greenland, and one in Iceland: these species approach certain American Vines. It is not difficult to form an idea of the vegetation of the polar regions, at the Miocene epoch, from the indications which we have just given. It consisted of forests of very various leafy and resinous trees, many of which had large leaves of very diverse forms; vines and ivy entwined these with their branches; and beneath their shade grew numerous shrubs and elegant ferns.

What a contrast between this picture and that presented to us by these countries in their present state! Now-a-days Greenland is nothing but an immense glacier, which covers the whole country and sends even into southern latitudes mountains of ice which cool the climate; we can scarcely say that a narrow belt along the shores is freed in summer and enabled to cover itself with a little vegetation. In the Miocene period the limit of Limes, *Taxodia*, and *Platani* was at 79° N. latitude; that of the Pines and Poplars, if we may judge from what we see in the present day, must have attained the pole, or at least the lands nearest to it; for they advance at present 15° further to the north than the Planes. It is a natural conclusion from this, that the extreme limit of trees then followed a line very different from that which we can trace at the present day: it now follows the isothermal line which gives a mean of 10° C. (= 50° F.) in July—that is to say, about 67° N. latitude; so that it scarcely passes the polar circle, whilst then it reached the pole itself.

This fact alone indicates that the climate was very different.

We may add other proofs to confirm our assertion. From the character of the flora of Spitzbergen at the Miocene period we may conclude that under 79° N. latitude the mean temperature of the year was 5° C. (= 41° F.); at the same epoch that of Switzerland was 21° C. (= 69°·8 F.), judging from the analogy of floras. There is consequently a difference of 16° C. (= 28°·8 F.); and for each degree of latitude the mean temperature has fallen 0°·5 C. (= 0°·9 F.) From this it follows that at Spitzbergen, at 78° N. latitude, the mean was 5°·5 C. (= 41°·9 F.), in Greenland, at 70°, it was 9°·5 C. (= 49°·1 F.), and in Iceland and on the Mackenzie, in latitude 65°, it was 11°·5 C. (= 52°·7 F.) These data suffice to explain the character of the flora of this period *.

The difference of temperature between Switzerland, in N. lat. 47° (brought by calculation to that of the sea-level), and Spitzbergen, in N. lat. 78°, is at present 20°·6 C. (=37°·08 F.), which gives a diminution of 0°·66 C. (=1°·2 F.) for each degree of latitude. It is therefore evident that at the Miocene epoch the temperature was much more uniform, and that the mean heat diminished much more gradually in proportion as the pole was approached, so that then the isothermal line of 0° (=32° F.) fell upon the pole, whilst now it is situated under 58° N.

It has been asserted that at the Miocene epoch currents might transport wood and vegetable remains to great distances, as is the case now, and that it is very possible that the plants which we find in the fossil state in the deposits of the polar regions may have been carried there in an analogous manner, and may not have lived on the soil where we find their remains. This notion cannot be admitted, as will be easily seen if we consider:—1, the perfect preservation of the leaves; 2, the enormous accumulation of fossil plants in the beds of siderolitic iron-ore in Greenland, associated with great deposits of lignites; 3, the fact that insects are found with the plants; and, 4, the presence of beech-leaves just issued from the bud and still folded, as well as that of flowers, seeds, and fruits associated with the leaves. Certain seeds are found arranged in the same manner as in the berry which protected them; this evidently indicates that the berry itself was buried in the mud. Now it is clear that a berry could not be carried by the waves to great distances.

Whoever will examine, without preconceived ideas, the

* For further details upon this subject consult the 'Flore fossile des Régions polaires,' by Prof. O. Heer (Zurich, 1867), in which all the plants of the Miocene epoch discovered in these countries are described and figured.

beautiful and varied fossil plants which fill the rocks of Ataneverdlak in Greenland, will be convinced that these plants cannot have come from a great distance. As to the fossil plants of Spitzbergen, it is very evident that they were not brought by marine currents, as we find them in freshwater deposits.

It appears certain, therefore, that at the Miocene epoch the temperature of the polar regions was much higher than in our day; and we are naturally led to inquire what are the causes which may have brought about such a change. We cannot admit the supposition of a displacement of the poles, even regarding it in the same way as Mr. Evans, who has recently maintained this theory. Indeed it is a certain fact that we remark the same phenomena all round the terrestrial globe, not only in the polar zone, but also under southern latitudes. No direct observation seems to us to confirm this hypothesis. We regard as much more important the theory according to which climatic modifications would coincide with modifications in the distribution of the seas and continents upon the surface of the globe. At present the extent of the seas is twice and a half that of the solid earth, and the continents are arranged in much more considerable masses in the northern hemisphere, and especially beyond the tropic. This condition is not normal. If, instead of so unequal a distribution, the lands and seas were equally distributed in all the zones, the temperate and glacial zones would enjoy a climate warmer than at present. Nevertheless, even supposing the most favourable distribution, we should not succeed in producing, between 70° and 79° N. latitude, a temperature sufficient for the development of a flora like that of which the existence in these regions during the Miocene period has just been indicated. Suppose all the continents united in the neighbourhood of the equator, and only a few islands left in the northern regions,—these would enjoy the highest mean temperature to which they could attain, their winters would be comparatively very mild, and yet the heat of the sun could not be sufficient between 70° and 80° N. lat. to allow of the development of a vegetation so rich as that of which we find the traces. Now it is certain that in the Miocene period there was a great extent of solid land in the temperate zone, and even in the polar regions, as is proved to us by the extension of several species of the Miocene flora, which we can follow from the Mackenzie to Spitzbergen.

The explanation of the climatic changes which the study of fossils reveals to us, has been sought in the fact that the gradual cooling of the mass of the globe must necessarily produce a gradual diminution of temperature. This cause may certainly have acted in the most ancient periods; but the Miocene epoch is too nearly approximate to our own to allow of our attributing to it, with any probability, the difference of temperature now indicated.

It seems to us to follow, from the preceding considerations, that it is from the study of phenomena of another kind that we must obtain the solution of the problem that we seek. Let us first examine, in the series of cosmical phenomena, the question of the changes which may have taken place in the position of the earth relatively to the sun. From the point of view which now engages our attention, a great importance has been quite recently attached to the periodical modifications of the eccentricity of the ellipse which is annually traversed by the earth. The form of this ellipse is modified within certain limits in the course of ages. At present it approaches a circle; in 23,900 years its eccentricity will have attained its minimum; then the orbit will again tend to acquire a more elongated form. The mean distance from the earth to the sun is 91,400,000 miles; when the eccentricity of the ellipse is at its maximum it has $\frac{1}{15}$ of this length, when it is at its minimum $\frac{1}{360}$; in the former case the earth departs from the sun 14,500,000 miles more than in the second case. At present the linear value of the eccentricity is three millions of miles. It must also be observed that, at present, the earth is nearest to the sun (at the perihelion) during the winter of the northern hemisphere, whilst in the summer it is furthest from it (at the aphelion). Now the relative position of the line of apsides and of that of the solstices is likewise subjected to a movement of revolution which is accomplished in 21,000 years. In about 10,000 years the summer of the northern hemisphere will fall at the period when the earth is nearest to the sun, and its winter at that when it is most distant. Of course the contrary will take place in the southern hemisphere.

It is assumed that during the periods when the eccentricity of the orbit of the earth approaches its maximum, when the perihelion coincides with the winter solstice, the northern hemisphere must enjoy a shorter and warmer winter, whilst the summer is longer and cooler. During this time the opposite is the case in the southern hemisphere. Its winter is longer and colder, its summer hotter and shorter, because the winter of this hemisphere corresponds with the greatest distance from the sun. Mr. Croll supposes that during this long and cold winter so great a quantity of ice must have been accumulated, that the summer following it (which, although hot, was short) had not the power to melt it entirely, and that it is at this epoch that we must place the *glacial period.* In the northern hemisphere, on the contrary, there would have been a continual spring, the summer being long and cool, and the winter short and warm. Mr. Stones has calculated that we must go back 850,000 years to reach the epoch at which the eccentricity of the orbit of the earth attained its maximum value, at the same time that the aphelion coincided exactly with the winter solstice in the northern hemisphere. The winter would then have lasted thirty-six days longer; and as it is at this period that the greatest quantity of ice and snow would have been formed, Lyell is inclined to place in it the glacial epoch. But 900,000 years ago, on the other hand, the orbit of the earth would have most nearly approached the circular form, and from this would have resulted a complete change of climatic conditions.

All these speculative theories are certainly ingenious, but it must be remarked that they have not a solid basis; in fact we still only very imperfectly know what is the extent of the action which might be exerted upon the power of the rays of the sun by the distance which they traversed to arrive at the earth. Lyell has pointed out, with reason, that according to Dove's calculation the earth is hotter in July (that is to say, at the moment when it is most distant from the sun) than in December (when it most nearly approaches it). The cause of this is the unequal distribution of sea and land in the two hemispheres, from which it results that the northern hemisphere has a hotter summer, even when the earth is nearest to the sun during the summer of the southern hemisphere. From this fact we may conclude that the mode of distribution of the sea and land on the surface of the globe exerts a *greater* influence upon the climate of each hemisphere than that which can result from the greater or less eccentricity combined with the position of the line of the apsides. On the other hand, however, as Lyell has admirably demonstrated, these two causes, by the combination of their effects, may have had an extremely important influence upon the changes of climate which the observed facts enable us to demonstrate.

It is also possible that the action of the sun has not always been the same; for, by the observation of its spots, we know that great modifications take place upon its surface, whence the possibility of a change in the intensity of the solar rays.

To all these considerations this one may be added:—The sun is not alone in the vault of heaven; millions of celestial bodies likewise shine there and diffuse their light and heat into space. Why, then, may we not suppose that the different regions of space have not all the same temperature? The mathematician Poisson put forward this idea, by calling attention to the fact that the number of stars is so great that they form, as it were, a continuous vault. We also know that the sun with its planets does not always occupy the same position in space; it probably moves round a fixed star situated at an infinitely great distance. Starting from these data, and supposing that the temperature of the different regions of space is not the same throughout, we should find a very simple explanation of the climatic phenomena which have been mentioned. Thus, if at the Miocene epoch the sun and its planetary system were in a region of space hotter than that in which they now move, this heat must have exerted an influence upon all parts of the terrestrial globe, but the effect must have been most marked in the glacial and temperate zones. If during this immense revolution, or solar year, hot periods succeed to colder ones, or *vice versâ*, we may by analogy assimilate the Miocene period to its summer, the glacial period to its winter, and the present period to its spring. It is evident that we must accept the idea of a course of prodigious length, the extent of which our minds cannot yet conceive. A time will no doubt come when we shall succeed in calculating it; and just as we now know the orbit of the earth, future generations may perhaps arrive at a sufficiently accurate knowledge of the orbit of the sun.

Our minds are confused, it is true, in presence of these spaces and periods which to us appear infinite; but this arises from the smallness of the scale according to which we measure space and time, as may be shown by a simple comparison. Suppose the duration of the life of man to be *a single day*; those born in winter could only know by tradition that there was formerly a time when it was hotter, and that this time would return after a long series of generations. The opposite would be the case with those born in summer. To these men of a day, a year would be a period of excessive length, since it would include 365 generations. Now the actual duration of human life corresponds not to a day, but perhaps scarcely to a minute of this great solar year; what inhabitant of the earth can ever know its phases? If he cannot conceive them with his bodily eye, he may do so at least with the assistance of his thought, with the aid of his intellect, which enables him to penetrate the obscurity of the past, and to coordinate the phenomena which have been accomplished in the course of successive periods. The eye of his mind penetrates into the most distant times, as into the remotest spaces of the celestial vault. If the body of man is small in contrast to the immensity of nature, if his life is short in presence of the infinite duration of time, what is not the grandeur and power of his mind, which carries him beyond the course of ages and gives him to understand that in his perishable envelope is deposited the germ of immortality!